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Methodological and Ideological Options

Revisiting ISEW Valuation Approaches: The Case of Spain Including the Costs of Energy Depletion and of Climate Change

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ABSTRACT

This paper develops an Index of Sustainable Economic Welfare for Spain from 1970 to 2012 and seeks to update valuation approaches to a number of items. Two approaches have proven particularly controversial over recent decades; the costs of energy depletion and of climate change. The valuation implications in measuring present welfare have proven problematic, as both include future sustainability consequences arising from resource depletion and environmental impacts. This study includes a '*transition cost*' approach to energy depletion, a modified approach to costs of climate change and water pollution, and removes the cost of ozone depletion. The results illustrate that while GDP per capita increased significantly, the ISEW per capita shows a widening gap. Household labour contributes strongly, but income distribution, energy depletion and costs of climate change limit improvement. Sensitivity analysis shows that accumulating climate change costs and escalating energy depletion costs have significant effects. Nevertheless, the new valuation approaches do not alter conclusions that welfare has shown little improvement. The ISEW provides a useful alternative to current indicators such as GDP subject to awareness of limitations. It is a measure of welfare that uses sustainability accounting methods when estimating costs, but is not an indicator of whether welfare is actually sustainable.

1. Introduction

The search for indicators of welfare, wellbeing and sustainability has hastened in recent years. The shortcomings of Gross Domestic Product (GDP) as a measure of welfare or socio-economic progress are increasingly acknowledged as GDP is a measure of the flow in market value of goods and services. It was originally intended only as a measure of national income by its instigator Simon Kuznets. Among many critiques, the Stiglitz Commission on the measurement of economic performance and social progress stated that while GDP has often been treated as a measure of economic wellbeing, confusing an economic indicator with one of welfare can lead to misleading indications and wrong policy decisions (Stiglitz et al., 2009). Criticism has included its failure to account for the value of household labour, the effects of income inequality, or losses due to environmental degradation and for wrongly considering defensive expenditures as contributions to welfare. Systems that supplement income such as the Human Development Index (HDI) (UNDP, 1999) have been advocated as measures of 'human development'. Stiglitz et al. termed a number of more complex measures that adjust for hidden costs and benefits as 'adjusted GDP' but which actually commence with household consumption rather than GDP. These began with the original Measure of Economic Welfare (MEW) of Nordhaus and Tobin (1973), to the Index of Sustainable Economic Welfare (ISEW) of Daly and Cobb (1989) and the related Genuine Progress Indicator (GPI) (Redefining Progress, 1995). Separate satellite national accounts of environmental indicators are also used to supplement the standard System of National Accounts (SNA) of economic activity. The ISEW is an aggregate welfare measure composed of economic values that integrate a macroeconomic measure of consumption, with distribution inequality of income, social impacts, environmental damage, environmental quality and items beneficial to welfare.

Since its inception, the ISEW has been applied to > 25 countries and more recently to dozens of studies of regions or states (Bleys and Whitby, 2015; Posner and Costanza, 2011). Within the field, the index has not been without controversy, particularly due to valuation

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methods (Neumayer, 1999), and Lawn (2003) has emphasised the need for more robust and consistent valuation methods. In the wider sphere of welfare indicators, the ISEW treatment of sustainability (Stiglitz et al., 2009), and the type of treatment of the links between consumption and welfare (Fleurbaey, 2009) have been questioned. Fleurbaey and Blanchet (2013) have pointed out the important contribution of the ISEW/GPI through the inclusion of resource depletion and distribution of income, but Lawn (2003) has also noted the problematic nature of consumption, suggesting a sensitivity analysis of excluding some categories such as 'cigarettes and tobacco' (Lawn, 2005). As yet, the varying contribution of different consumption categories to human wellbeing is a nascent field of research which requires further development (Stanca and Veenhoven, 2015). Lawn (2014) has actually advocated a possible return to the original Nordhaus and Tobin title of 'Measure of Economic Welfare', to avoid confusion with measuring 'sustainability' or all that is entailed by 'genuine progress'.

This paper is the first national estimate of an ISEW for Spain. It seeks to address prominent controversies in ISEW valuation methods, the implications for welfare in Spain, and for the wider use of the index itself. Spain is an interesting case study as it emerged from the Franco dictatorship between 1975 and 1978. It is perceived to have engaged in a development catch-up from the mid 1980's through GDP growth, and it experienced a deep economic recession that began in 2008. While the development of the ISEW/GPI has concentrated on expansion to more countries with standardisation of the approach, Bleys (2008) sought to improve the two controversial valuations; depletion of non-renewable resources and the long-term costs of climate change. Both remain problematic and have been the subject of ongoing debate for almost twenty years. The study returns to these valuations termed for brevity; '*energy depletion*'[2] and the '*costs of climate change*'. Bagstad et al. (2014) discussed how it is necessary to revisit the component list in studies such as GPI, to ensure that it represents the range of benefits and costs to welfare that are currently well recognised in the social science, environmental, and economic literature. Following Bagstad et al. we reviewed all of the items used to calculate an ISEW. In addition to focussing on energy depletion and the costs of climate change, we also modified the approach to calculating the costs of water pollution and omitted the place of ozone depletion. The approaches used to estimate all of the items in the Spanish ISEW are detailed in the supplementary materials.

Following the introduction, the paper is structured as follows; Section 2 provides detail on the methodological approach to update valuations of energy depletion, the costs of climate change, the costs of water pollution, and a re-consideration of the place of the costs of ozone depletion. Section 3 presents and interprets the results of the Spanish ISEW, Section 4 provides a discussion of implications for Spain and for wider application of the index and Section 5 provides concluding remarks.

2. Methodology

Since the development of the early ISEW studies there have been important changes in the relative importance, understanding and valuation of key indicators used to calculate the index. These have reflected the changing scientific and policy agenda, such as the increasing focus on climate change and energy, and declining in the case of ozone depletion. While the approach used here is based on the earlier antecedents (Daly and Cobb, 1989; Cobb and Cobb, 1994; Jackson et al., 1997), and updates to these approaches that have followed in the literature in the intervening years such as Bleys (2009), as noted by Bleys (2008), a complete discussion of the approach, data sources and assumptions is crucial with an ISEW. For transparency, replicability and comparability the other items calculated are comprehensively documented in the supplementary material to this paper. The period from 1970 to 2012 is chosen due to availability of more comprehensive data with less gaps, allowing greater confidence in underlying data while retaining a period of sufficient length for long-term trends to emerge. Table 1 gives an overview of the items included in the Spanish ISEW study; its impact, rationale and a short summation of the methodology. All data is converted into constant 2010€ prices, using the appropriate exchange rate (ECB) and GDP deflator (World Bank) where relevant. Changes in Net Capital Growth and Net International Investment Position have been excluded from the final index as recommended by Bleys (2008) as they are not compatible with the Fisherian concept of income (Lawn, 2013) which constitutes the theoretical basis of ISEW/GPI. The cost of ozone depletion has been excluded from the index on the basis of re-consideration of its place within the ISEW as is discussed in Section 2.3. This follows the suggestion of Bagstad et al. (2014) and the limitations in the valuation of the social cost of ozone depleting substances that are discussed in this study.

2.1. Depletion of Non-renewable Resources as 'Energy Depletion'

Since the inception of the ISEW the depletion of non-renewable energy (Item S) has changed in focus and valuation, and proven controversial. Daly and Cobb (1989) originally used the more broad *mineral resources extraction cost* as the reference, with subsequent studies varying by using national consumption or production. The valuation was then applied to the reference consumption or production quantity as either total resource rents or the El Serafy method (El Serafy, 1989) was used to calculate resource user costs. Cobb and Cobb (1994) modified item S substantially, with the new method based on a *replacement cost*, intended as the theoretical cost of future replacement of non-renewable fossil fuel and nuclear resources with renewables. This cost was valued as an arbitrary $75 in 1988 per barrel of oil equivalent (BOE), with an escalating increase of 3% each year. The approach reflected the relative infancy of knowledge in the area at the time, and according to Bleys (2009), has been the most commonly applied in ISEW studies. It has however proven controversial owing to a perceived high cost of substitution and the escalating cost factor (Neumayer, 1999). Neumayer (2000) suggested that while renewables were expensive in the late 1990's, a declining replacement cost would likely be more valid. In response, Bleys (2008) sided with Neumayer and excluded the escalating cost factor. Bleys continued with the Cobb and Cobb cost in the absence of sufficient knowledge of transition costs. In Diefenbacher et al. (2013) the Nationalen Wohlfahrtsindex or National Welfare Index (NWI) for Germany, the authors suggest that non-renewable energy can be consumed only if renewable energy sources are built up at the same time in order to guarantee future energy supply. Annual costs were estimated by multiplying the quantity of final non-renewable energy by a corresponding price for renewable energy as a replacement cost. They employ a current price for renewable energy rather than a future cost and consequently do not address the timing of replacement or the inevitable change in cost in the future. Knowledge of the mechanisms and costs of energy transition have evolved considerably in recent years, but arriving at a refined valuation approach requires some framing conditions; technically, ethically and economically.

As a contributor to development, the age of fossil fuels may come to be seen as a blip in the history of civilisation. An important contributor to how past human progress unfolded since the industrial revolution, it came with numerous hidden costs; now known as potentially catastrophic in the form of anthropogenic climate change and highly disruptive in the form of depletion and peak production. A dominant place for fossil fuels in future development trajectories is now anathema to a sustainable and secure future. Following a hardening of the science of climate change; by cause, impact and response since the early 1990's, policy and legal processes are now moving inexorably towards ushering the end of the fossil era. The pathway is becoming clearer as avoiding

[2] Including both fossil fuels and nuclear as non-renewable energy resources.

Table 1
Summary of the approach to items estimated or omitted in the ISEW for Spain.

	Item	Impact	Rationale	Methodology
A	Years		Bound on scope	1970 to 2012
B	Consumer expenditure	+	Personal consumption measure	From national accounts
C	Income distribution inequality		Effects of distributional inequality	Gini coefficient based on income
D	Weighted personal consumption expenditure	B/(1 + C)	Consumption weighted by income distribution	Item B/(1 + Gini coefficient)
E	Services of household labour	+	Value of domestic labour	Time spent on household and volunteer labour valued by shadow price of domestic worker.[i]
F	Services of consumer durable	+	Capital adjustment	22.5% of value of stock of durable consumer goods
G	Services from public infrastructure	+	Non-defensive public expenditure	Government expenditure on roads
H	Public expenditure on health and education	+	Non-defensive public expenditure	Half of government expenditures on health and education
I	Expenditure on consumer durables	−	Capital adjustment	National accounts of durable consumer goods
J	Private expenditure on health and education	−	Defensive private expenditure	Half of private expenditures on health and education
K	Cost of commuting	−	Defensive private expenditure	30% of private transportation cost of vehicles and transport services
L	Cost of personal pollution control	−	Defensive private expenditure	Defensive expenditures on pollution abatement and control[ii]
M	Cost of car accidents	−	Defensive private expenditure	Road accidents by direct and indirect costs of three accident categories, and an actuarial valuation of willingness to pay to reduce risk
N	Cost of water pollution	−	Environmental degradation	Tonnes of water contaminants by Spanish treatment costs
O	Cost of air pollution	−	Environmental degradation	Emissions of SO_2, NO_x, CO, PM_{10} and NMVOC by marginal social costs
P	Cost of noise pollution	−	Environmental degradation	Noise of agglomeration, roads, trains and airports by individual cost[iii]
Q	Protection of wetlands	+	Natural capital conservation	Hectares of protected wetland by system cost
R	Loss of agricultural land	−	Natural capital depletion	Loss by market value of agricultural land[iv]
S	Depletion of non-renewable energy	−	Natural capital depletion	Primary fuel consumption by 'transition cost'
T	Costs of climate change	−	Long-term environmental degradation	Emissions of the six Kyoto GHGs by the social cost of carbon[v]
U	Cost of ozone depletion	−	Long-term environmental degradation	CFC production by damage cost[vi]
V	Net capital growth	+	Capital adjustment	Net capital stock by capital requirement[vii]
W	Change in net international position	(+/−)	Capital adjustment	Net international investment position[viii]
X	ISEW		Total ISEW	Aggregated indicator
Y	Population		Total Population	From national accounts
Z	GDP		Total GDP	From national accounts
AA	ISEW per capita		Final welfare indicator	Total ISEW/population
AB	GDP per capita		Comparative indicator	Total GDP/population

[i] Data on volunteer labour in item E is only available for 2010 and volunteer labour is omitted from the final index.
[ii] Item L is omitted from the index due to lack of data.
[iii] Data for Noise Pollution (P) is only available for 2009 and item P is omitted from the final index.
[iv] Soil erosion, usually calculated in item R, is omitted from the final index due to lack of data.
[v] Item T is the long-term global costs of damages that will arise from climate change discounted to the present. These costs are specifically attributable to Spain as they arise due to emissions of GHGs on Spanish territory. This cost does not specifically account for a seperate branch of the costs of climate change, in the form of current national damages. Current national damages from climate change are attributable to historic emissions from all nations globally that impact on current national welfare. There are limitations in knowledge of current national costs, see the explanation of Item T in Section 2.2.
[vi] Item U has been estimated in this study but omitted from the final index. This is due to declining issue importance and limitations in cost estimations in the literature. See Item U in Section 2.3.
[vii] Item V has been estimated in this study but omitted from the final index as it is not compatible with the Fisherian concept of income, see Lawn (2013).
[viii] Item W has been estimated in this study but omitted from the final index as it is not compatible with the Fisherian concept of income, see Lawn (2013).

'dangerous anthropogenic interference' with the climate[3] is widely acknowledged as requiring − 80 to − 95% reduction in greenhouse gas (GHG) emissions in industrialised countries by 2050, with all countries near zero by 2100 (Metz et al., 2007). This resolves a central issue in terms of ISEW valuation, the cost implications of the timing of replacement. Neumayer (2000) was critical of the assumption that all resource depletion needed to be replaced annually, in the present, citing that a rational resource extractor would exploit the available and cheaper non-renewable resources first. Lawn (2005) agreed that it may not be necessary to think about replacing non-renewable energy for some time, but as an accounting issue, it is necessary to attribute the cost to the point in time at which the depletion took place. However, the ecological space to emit GHG has been squeezed and has reached or is approaching various biophysical limits due primarily to combustion of fossil fuels. Climate change provides the framing conditions for a transition away from non-renewable energy to renewables.

On the basis of the increase in the number of modelling exercises to understand transition, this study updates the valuation by adopting an energy '*transition cost*' approach. The 2050 no-nuclear reference scenario from Vallejo et al. (2013) is used, who report the global average Levelised Cost of Electricity (LCoE)[4] in 2050 as a net present value of \$93.6/MWh in 2010\$ which converts to €70.75/MWh. The Vallejo et al. study is particularly useful; it involves a decarbonisation track to halve global CO_2 by 2050, the LCoE is a global average across all technologies, hence more broad than just electricity. It also involves gradual transition with biomass, biofuels, carbon capture and storage

[3] Defined as a > 2 °C change in global average temperature on pre-industrial by 2100, it is now variously committed to including; a global political agreement at UNFCCC COP 16 and is a legal commitment within the EU. It is also substantially supported by an agreement at the 2015 G7 meeting to phase out fossil fuel use by 2100, and various recent national commitments including that by China to peak GHG emissions by 2030. The 2015 Paris Agreement under the UNFCCC is now formalising this requirement and seeking to pursue efforts to limit the temperature increase to 1.5 °C.

[4] The LCoE is a useful indicator of the lifetime cost of producing energy calculated through capital investment, to operation and maintenance and fuel costs.

and a continuing albeit minor role for fossil fuels. This transition consequently addresses Neumayers' concern regarding the timing of replacement, while the exclusion of nuclear addresses the requirements of the ISEW. The cost chosen is comparable to the lower end of the 2050 decarbonisation pathways described for Europe (ECF, 2010). The LCoE is a system cost that includes operation and maintenance but it is the capital investment component alone which must be separated for equivalence with the value of depletable non-renewable energy in the Earth's crust.[5] LCoE's vary considerably by technology, by cost of capital etc. but current renewable energy LCoE's vary predominantly between 70 and 85% of the full LCoE (IPCC, 2011), and 70% is conservatively chosen to adjust the LCoE for turnkey investment costs only. Converting to €/tonne of oil equivalent gives a cost of €822.85 and modifying this for investment costs only, using the 70% factor, gives a final transition cost of €575.99 per tonne of oil equivalent in 2010€. Following this transition cost, the primary energy requirement of non-renewable energy in Spain is used as the reference. Data for; coal, oil, gas and nuclear are obtained from the Spanish Energy Ministry from 1973 to 2012 (MINETUR, 2009; MINETUR, 2013), with the remainder extrapolated on a five year trend.

The implications of the new *transition cost* approach are compared against the approach from Bleys (2009) and Cobb and Cobb (1994) in Fig. 1 below. The new transition cost approach as developed in this study is included in 'ISEW/capita transition cost'. The Bleys approach ('ISEW/capita replacement cost no escalation') includes the Cobb and Cobb replacement cost commonly used in ISEW studies but without cost escalation while the Cobb and Cobb approach ('ISEW/capita replacement cost with escalation') includes the Cobb and Cobb replacement cost and the escalation.[6] The new valuation by transition cost gives a lower depletion cost than that when using the Bleys approach and the resultant ISEW per capita is marginally higher. From the early 1990's onwards, the cost escalation in the Cobb and Cobb approach increases the cost of depletion. It changes the trend in the resultant ISEW per capita Cobb and Cobb, removing most of the minor improvement in the overall index that is evident when using the transition cost and Bleys approaches.

2.2. Costs of Climate Change

In calculating the costs of long-term environmental damage, ISEW studies have typically applied a long-term damage cost of climate change attributable to CO_2 emissions, Item T in the Spanish ISEW. Daly and Cobb (1989) estimated damage from fossil fuels of $0.50 per BOE in 1972 USD. This imprecise method was updated by Jackson et al. (1997) applying an early valuation of the Social Cost of Carbon (SCC) from Fankhauser (1994) at $20 per ton of CO_2 in 1990, but it is now widely acknowledged as a conservative cost. It was applied to CO_2 emissions alone, emissions were added cumulatively from year-to-year and the damage costs were varied annually by reference to historical global CO_2 emissions since 1900. Neumayer (2000) was critical of this cumulative assumption, applied in all ISEW/GPI studies at the time with the exception of the Australian GPI study (Hamilton, 1999). The SCC theoretically includes all future damages from a ton of CO_2 discounted to the present and therefore accumulation would lead to multiple counting of future costs. Lawn (2005) defended that an ISEW is a measure of welfare experienced by a nation's citizens in that year, in which the consequences of past activities are strongly implicated and for which citizens require compensation. Bleys (2008) updated the approach, but rather than endlessly accumulating GHG, a linear depreciation model of atmospheric stock is applied. The marginal social cost was varied through time by reference to atmospheric concentrations at Mauna Loa, and the low damage cost valuation of Fankhauser was used. Talbert et al. (2007) utilised a mean of the SCC in the literature of $89.57 in 2000$. They applied a linear model of increase in marginal damage costs from 1964 as an 'overshoot year' but used the cumulative approach to emissions and therefore costs.

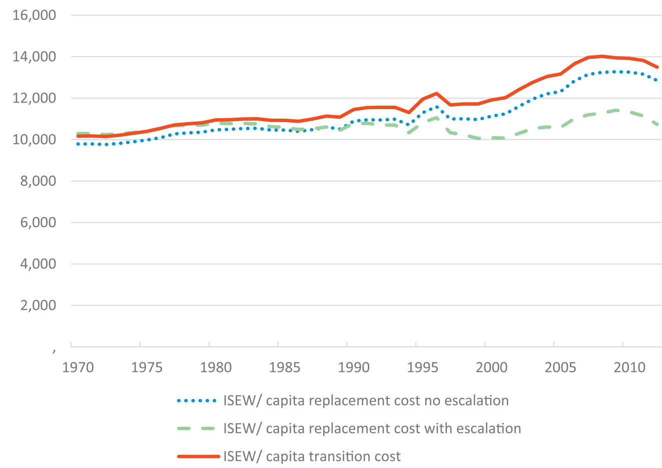

Fig. 1. The effect of alternative energy depletion valuation approaches on the Spanish ISEW per capita in 2010€.

However, all of these approaches are somewhat problematic. The accumulated costs in Jackson et al. and Talberth et al. are not in line with how an SCC should be applied. Bleys used atmospheric lifetime to limit accumulation, but an accumulation still appears to have been used. The factors influencing the costs of the impacts of climate change are complex and multifactorial. The impacts of climate change, both physical and monetised, do not have a direct linear relationship with either historical emissions or atmospheric concentrations. Both the stock of emissions and atmospheric lifetimes are theoretically included in a modelled SCC result. Future damages are then discounted to the present giving a damage curve for a ton of CO_2 emitted in a particular year. This damage curve was included in the original Fankhauser study from 1991 to 2030, suggesting that the adjustments were unnecessary as the curve could theoretically be extrapolated backwards.[7] It renders the approach to changes in the damage curve problematic in Jackson et al., Talberth et al. and in Bleys. Lawn (2005) is valid from a damage cost perspective in stating that current welfare impacts require inclusion, and also that some type of accumulation should show permanent losses consistent with strong sustainability (Lawn, 2014). Nonetheless, Neumayer (2000) is correct from a damage valuation perspective, as accumulating costs with an SCC is not an appropriate approach to achieve this. An SCC already includes future permanent losses in its increasing marginal damage curve, discounting all future losses back to the present. However, this valuation is incomplete if the damage valuation does not adequately account for current welfare losses from climate change, on an annual basis, in the period of the ISEW measurement.

These issues require separation in the approach to the ISEW for accurate accounting; as i) the future long-term global impact costs from a unit of emissions in each year (arising due to current national GHG

[5] Theoretically, it is the value of the potential non-renewable energy in the Earth's crust that should be replaced unit-for-unit in an ISEW to measure energy depletion. Operation and maintenance costs must therefore be subtracted from the LCoE for equivalence. The resultant potential energy in installed renewables has an advantage over non-renewable energy in that there are no fuel extraction costs. This makes the depletion valuation effectively cheaper than a direct equivalence. In addition, as the 70% capex rate is chosen, depletion has already occurred, fossil fuel extraction costs are increasing and other functions such as petrochemicals cannot be easily replaced, the approach taken is therefore conservative in valuing depletion.

[6] Converted and inflated to 2010€ it is €117.88.

[7] Some damage curves are linear and some are exponential, but most accelerate over time (Anthoff et al., 2011), with CO_2 just one of the factors determining future damage costs.

emitting activities), but also ii) the current national welfare costs of climate change impacts (arising due to past global GHG emitting activities). While the SCC chiefly values discounted global costs of impacts in future years, it can have limitations in how it handles impacts and costs in initial decades (Anthoff et al., 2011), and costs are necessarily global and not national. It is necessary to improve knowledge of the cost of current national impacts of climate change, but there is initial evidence that current costs in Spain, while significant, are not sufficient to substantially alter the recent trend in the ISEW per capita.[8]

According to Lawn (2005), the cost of climate change in an ISEW constitutes a compensatory fund. It is essentially a Pigouvian tax which must be sufficiently high to compensate domestic citizens for current impacts, but equity also requires compensation for global and future impacts, and it is here the SCC becomes more complex. There are inevitable escalating impacts but also potential catastrophic and irreversible impacts for which, at the least, a risk premium is required. This is a controversial ethical issue and the discount rate has become a key battleground. A prominent question is then: what level of SCC is indeed appropriate? Additional modelling could refine the monetisation of the current welfare impacts, but it is likely that more significant are issues such as the discount rate and damage functions, and their influence on the level of the chosen SCC. A prominent estimate in the literature from the US, of $33 in 2010 in 2007$[9] per metric ton of CO_2 (Interagency Working Group on the Social Cost of Carbon, 2013) is actually similar to that commonly applied in previous ISEW studies. The Fankhauser cost of $20 per ton of CO_2 in 1990 inflates to $33.37 in 2010. It must be noted, that it has been widely acknowledged that such valuations are conservative and too low (Pachauri and Reisinger, 2007; Interagency Working Group on the Social Cost of Carbon, 2013). Despite updates of damages modelled by Integrated Assessment Models (IAMs) there are notable limitations in the inclusion of all relevant climate change impacts and risks, and there is much criticism of the discount rate of 3% applied.[10] The literature has failed to agree on what this discount rate should be, and the cross-over with ethics, values and politics are inescapable in these decisions. Ackerman and Stanton (2012) explore alternative SCC's varying the discount rates, damage functions and climate sensitivity, yielding far higher SCC estimates of up to $893 in 2010.[11] Ackerman and Stanton suggest strong arguments to increase the cost to $150 – $500. This SCC range is in line with the recent study of Moore and Diaz (2015) recommending an SCC of $220 per ton of CO_2. In Diefenbacher et al. (2013) for the German NWI, the costs of climate change were estimated by multiplying the national GHG inventory annually by a damage cost of €74 in 2005 as a 'best guess' approach on the range of SCC's in the literature. The Diefenbacher et al. approach is an improvement as accumulation of costs was avoided and also as all GHG are included. However, a damage curve was not applied and the 'best guess' damage cost may be insufficient. It could be argued that it is skewed downwards as the recent advances in costing the SCC range have shown.

The Spanish ISEW seeks to simplify, revise and expand the valuation of the costs of climate change by; reviewing and updating the method, revising the damage cost and applying this to all GHG's commonly known as the 'basket of six'[12] rather than just CO_2 emissions as in earlier ISEW studies.[13] This is possible by; i) obtaining an appropriate SCC[14], ii) varying the SCC annually by its modelled damage curve and iii) applying this to an inventory of total GHG. Following the rationale of the SCC discussion above, this study adopts a higher value SCC than previous ISEW at $232 in 2010$ per tonne of CO_2.[15] It translates to €175.37 in 2010€ per tonne of CO_2 modified on a damage curve of 1.9837% compound growth per annum following Ackerman and Stanton's damage curve. This costing is still from the lower range of Ackerman and Stanton (2012) and is compared against the even lower SCC from Fankhauser (1994) as a sensitivity test of different SCC's. The SCC is varied each year following the damage curve detailed in Ackerman and Stanton extrapolated back to 1970. Using this approach to vary the damage curve of the SCC follows the principle of 'Occam's razor'. It appears more simple and robust, maintains a stronger mathematical link with modelled damages, avoids an arbitrary beginning year, and allows for accelerating damage costs rather than assuming a linear link with global emissions or atmospheric concentrations. For the inventory of GHG, data on the basket of six are available from (MAGRAMA, 2014) from 1990 to 2012. Reported in Gigagrams (Gg) by CO_2 equivalent this allows aggregation across all GHG's. From 1970 to 1989, CO_2 data is obtained from the Carbon Dioxide Information Analysis Centre (Boden et al., 2015), with the other five gases extrapolated by the rate of change in CO_2. The annual multiplication of the emissions flow inventory does not lead to accumulating damages, addressing Neumayer (2000). Current national welfare losses arising from the impacts of climate change are subject to the modelling limitations described in Anthoff et al. (2011), meaning that the SCC reflects long term global damages. Current national welfare losses arising from the impacts of climate change from past global emissions of GHG are omitted due to lack of data. This is restricted to one data point from 2010 in the report of Fundación DARA Internacional (2012).

The new valuation is compared with the approach frequently used in previous ISEW/GPI studies to determine the effect on observed results, and also with using an alternative lower cost of SCC. The index resulting from the updated approach is plotted in Fig. 2 in 'ISEW/capita Ackerman and Stanton cost,' against the approach developed by Jackson et al. (1997) that used the Fankhauser (1994) cost and accumulation of emissions in 'ISEW/capita Fankhauser cost accumulating'. The alternative lower SCC cost per tonne of CO_2 is taken from Fankhauser (1994). It uses Fankhauser's damage curve rather than accumulating emissions, and is represented by 'ISEW/capita Fankhauser cost non-accumulating'. When viewing the difference between the new valuation approach and the approach of Jackson et al. (1997) the change is significant. In 2012 the index reduces from €13,498 per capita to €7501 using the Jackson et al. approach. This is based on costs of climate change of €45.968 billion calculated in the approach of this study that increase to €194.597 billion using the Jackson et al. approach. The index using the Jackson et al. approach leads to a welfare per capita that begins at a lower level (€8665 in 1970 compared to €10,167 in the new approach) and slightly declines over the study period. Using the lower SCC cost from Fankhauser leads to a significantly lower cost of climate change (€8198 billion in 2012 as opposed to €45,968 billion following the higher SCC adopted in this study) but only marginally affects the overall index (at €14,305 per capita in 2012 compared to €13,498 using the higher SCC adopted in this study).

2.3. Cost of Ozone Depletion

The cost of long term environmental damage in the form of ozone depletion was an early controversy with the ISEW. Damage to the ozone layer is known to cause harm to the 'economic' activities of agricultural production, fisheries and materials but also to human health

[8] Fundación DARA Internacional (2012) have estimated Spanish losses from the impacts of climate change as 0.5% of GDP in 2010, which equates to €5.41 billion.

[9] $34.71 in 2010 prices.

[10] Analyses have shown that SCC estimates can vary two times depending on assumptions about future demographics, three times due to uncertainty and at least four times owing to differences in discounting and damage functions (Arent et al., 2014).

[11] At a 1.5% discount rate, 95th percentile climate sensitivity and Hanemann Weitzmann damage functions.

[12] All six Kyoto protocol GHG; carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).

[13] In the German NWI, Diefenbacher et al. (2013) used all GHG's in the national emissions inventory.

[14] It is worth noting that the social cost will vary by GHG, but as the accounting is on the basis of CO_2 equivalents this is offered as a suitable proxy.

[15] At a 3% discount rate, 95th percentile climate sensitivity and Hanemann Weitzmann damage functions.

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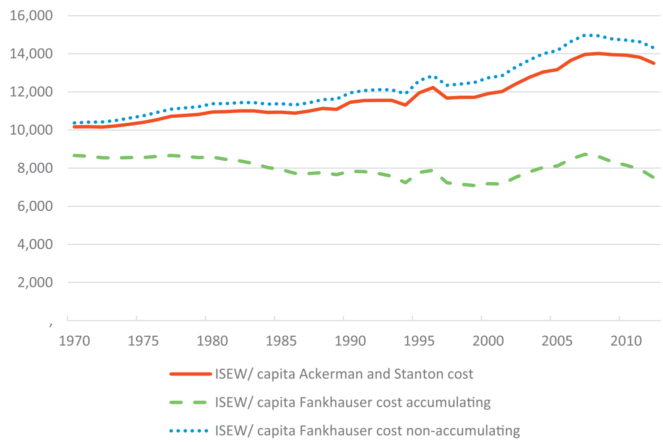

Fig. 2. Comparison of the effect of alternative approaches to calculating the costs of climate change on the Spanish ISEW per capita in 2010€.

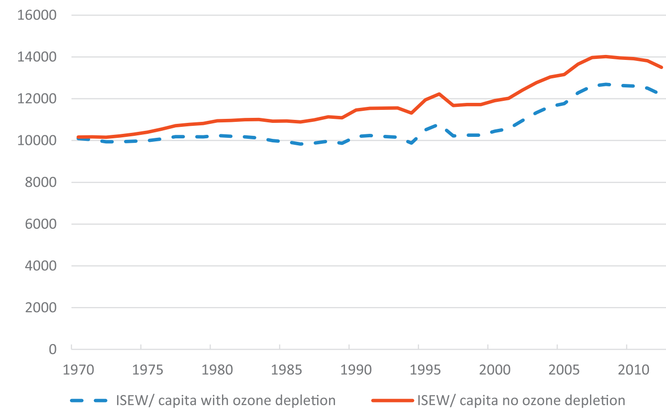

Fig. 3. Comparison of the Spanish ISEW per capita with and without the cost of ozone depletion in 2010€.

(Environment Canada, 1997) and to other types of natural capital. Cobb and Cobb (1994) incorporated such a cost of long-term environmental damage from chlorofluorocarbons (CFC). This was set at a unit cost of US$15 in 1972 prices for each kilogramme of cumulative world production, of CFC-11 and CFC-12. Jackson and Marks (1994) extended the list of harmful ozone depleting substances (ODS) to include all Montreal protocol listed CFCs: CFC-11, CFC-12, CFC-113, CFC-114 and CFC-115. In addition, they calculated a unit cost with the ratio of the cumulative consumption of CFC-11 and CFC-12 to the cumulative consumption of all Montreal listed CFCs, based on the weighting of the Cobb and Cobb cost. Jackson and Stymne (1996) used CFC consumption rather than production figures as some countries do not produce CFCs.

According Metz et al. (2005), the estimation of the cost of damage caused by a unit of ODS could be assisted by the same the methodological advances used in calculating an SCC, and would allow discounting of future impact costs to the present. The study by Environment Canada (1997) is regarded as the most comprehensive global cost study that has been undertaken, with the benefits of the implementation of the Montreal Protocol estimated at €400 billion in avoided global economic costs. A number of avoided human health impacts were also estimated; 20 million reduced cases of skin cancer; 130 million reduced cases of eye cataracts and 335,000 reduced skin cancer fatalities, but these were not monetised as the study was completed before the necessary methodological advancements from calculating SCC's. Other analysis has suggested a US cost of 4.23 trillion in 1990$ (USEPA, 1999)[16] but without the required detail reported to attribute it to a unit of ODS.

The approach to valuing the damage cost of ODS used here follows that of Bleys (2009). The damage cost of 53.71€ per kg CFC equivalent in 2000€ taken from Jackson et al. (1997) is used, which inflates to €70.74 in 2010. This cost is then applied to an accumulation of CFC's as per Bleys rather than a once off annual cost as was possible in estimating the costs of climate change. In attributing responsibility it is appropriate to use either production or consumption statistics, but not both to avoid double-counting. Data for CFC consumption are aggregated at the European Union level, but data for Spanish CFC production is available from 1986 to 2009[17] (UNEP, 2013). From 1970 to 1985 production is assumed constant at the level in 1986 rather than a trend line extrapolation which would likely over-estimate historical production levels. For 2010 to 2012 an extrapolation is used based on the trend from 1995 onwards, the period of the Montreal protocol and declining production.

[16] The Net Present Value of the economic benefit of avoided impacts of ODS on human health, agriculture, ecological effects and material damage, arising from the US Clean Air Act at a 2% discount rate estimated from 1990 to 2175.

[17] This study only includes data for CFC's and excludes CCl_4 and HCFC's. Both have declined significantly or become negative in the last decade due to destruction.

As per Metz et al. the ideal approach to calculating damage costs of ozone depletion would derive a social cost that discounts future costs to the present. This cost could then be applied annually to each unit of ODS. Bagstad et al. (2014) suggested that it is possible to omit the cost of ozone depletion as the ozone layer has been recovering slowly since the early 1990's, and there has been a consequent change in global environmental policy priorities. This cost was omitted by Castaneda (1999) in the ISEW of Chile and by Stockhammer et al. (1997) for Austria. Owing to the lack of appropriate valuations of the social costs of ODS and the suggestion of Bagstad et al., we have omitted the cost of ozone depletion from the Spanish ISEW. The effect of excluding the damage cost of ozone depletion is compared against its inclusion using the established approach in Fig. 3. Although the cost is substantial when it is included and the trend in the index is reduced until to the mid-1990's, it then follows a similar trend to the index that excludes this cost, and does not change the conclusion that the ISEW per capita has experienced a minor improvement over the study period.

2.4. Cost of Water Pollution

The cost of water pollution, included as item N in the ISEW, is an environmental degradation that reduces welfare and sustainability. Relevant water resources include: inland surface water, coastal waters, ground waters and reused water. Daly and Cobb (1989), used a cost specific to the USA, subsequently used in other ISEW studies. Other relevant valuations include siltation as per Daly and Cobb (1989) and the cost of water treatment. Recognising that this cost was specific to the USA and that the valuation is now almost 45 years old, this study employs a contemporary Spanish specific valuation. Our method uses water treatment costs and only pollution costs for river water resources. The cost of water treatment is considered a valid approach and using it also overcomes data limitations that prevent the application of the original Daly and Cobb method in the Spanish case. Based on estimations of total water contaminant quantities and costings for water treatment from a study of Valencia (Hernández-Sancho et al., 2009), this is an attempt to update the Daly and Cobb approach. Due to limits on data availability, only river water resources are used, and the following indicators relevant to water pollution; chemical oxygen demand (COD), biological oxygen demand (BOD), suspended solids (SS), nitrogen (N) and phosphorus (P) in treated water supply. Data is obtained from INE for the period 1996 to 2006 (INE, 2011). As the trend varies by indicator, for COD, BOD and SS the remaining years are extrapolated based on changes in GDP whereas for N and P the historical trend is used. This reflects the greater importance of recent policy through

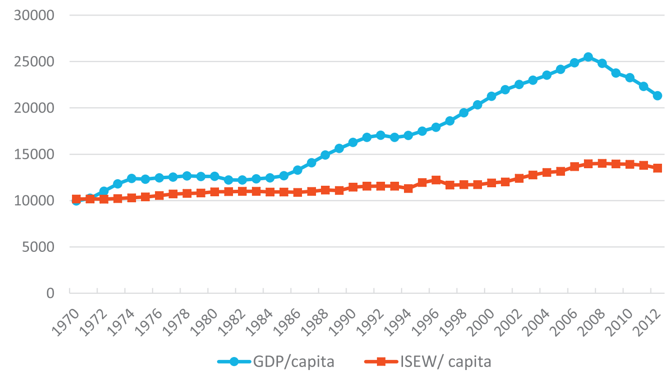

Fig. 4. ISEW per capita and GDP per capita in Spain from 1970 to 2012 in 2010€.

European Directives in the driving change in N and P. The costs are shadow prices for river water treated in 2004: 16.353 €/Kg of N, 30.944 €/Kg of P, 0.005 €/Kg of SS, 0.033 €/Kg of BOD and 0.098 €/Kg of COD (Hernández-Sancho et al., 2010). A standardisation of valuation approaches in general is a desirable development but there is a strong argument that the actual monetary valuation of costs should be localised where they are context-driven. A comparison of the effect of the new valuation approach against that used in Daly and Cobb (1989) is not applied due to data limitations.

3. Results and Interpretation

For the ISEW and GDP per capita in Fig. 4, the gap and the difference in trend is considerable and immediately evident. The ISEW per capita trended below GDP per capita from 1970 until 1985 when the indices begin to diverge. GDP per capita increases in the early 1970's followed by a decade of stagnancy. In the post-Franco era with accession to the European Community in 1986, GDP per capita began to grow rapidly but the ISEW per capita scarcely grows until 1999 when it commences a slow increase. As the Spanish economic recession '*la crisis*,' commences in 2008, GDP per capita experiences a sharp drop while the ISEW per capita shows a small downturn. The overall pattern suggests that accounting for social and environmental costs and benefits, the contribution of a growing economy to average welfare have been dubious in Spain. Despite significant increase in GDP per capita recorded over the forty two years, the ISEW per capita illustrates only a minor improvement.

The short period of improvement from 1999 to 2007 is predominantly attributable on the positive side as items that act to boost the index; through an increase in consumption expenditure (B), household labour (E) and public expenditure on health and education (H), and to declines in the cost of air pollution (O) and of car accidents. During this period there are also items that act to decrease the index through rising income distribution inequalities (C), and increases in the cost of climate change (T), of energy depletion (S) and of commuting (K). The downturn in the index during the recession from 2007 to 2012 sees a decrease in personal consumption expenditure and increasing inequality (Item D), loss of farmland (R), a decline in expenditure on consumer durables and a decline in public expenditure on health and education (H). Items that act to soften the decrease in the index include; a continued increase in the value of household labour (E), and declines in the cost of energy depletion (S), costs of climate change (T), cost of air pollution (O) and the cost of car accidents (M). Further understanding of the overall trends can be facilitated by analysing the items that influence the pattern in the ISEW recorded in Table A1 and A2 in Appendix A.

Weighted personal consumption (item D) increased steadily, peaking in 2007 as the economic recession takes effect in 2008. The variation in the Gini coefficient from income distribution (Item C) from a maximum of 0.37 in 1973 to a minimum of 0.24 in 1988, followed by a return to 0.35 in 2011, is a drag on welfare as it is used to weight the contribution of consumption. While the post-Franco years showed a drop in inequality, accession to the EU and the growing economy have been accompanied by a growth in inequality. The single biggest adjustment, and the largest positive, is the benefit provided by the value of household labour in item E. This benefit counters a worsening in other items, with a prominent boon for welfare. While the average time spent per day on home and family care has declined overall since 1970, population climbed and the participation rate increased, likely due to cultural changes in gender roles. It may be tempting to conclude that the cultural significance of the family in Spain leads to large quantities of time expended on household activities, but the only comparative survey from 2000 (Eurostat, 2012) places Spain at the lower end of the range of European countries. Time Use Survey data shows that time for home and family care did increase in Spain between 2000 and 2003. Recognising that household labour is valued by the shadow price of Spanish domestic labour[18] and not by opportunity cost, its contribution to welfare in Spain is a significant finding, even though relatively smaller than the contribution of household labour in the recent Belgian index (Bleys, 2009). Public health and education (H), although much smaller, is the next largest positive in the index. It also began declining steeply in 2010 as austerity policy was used in an attempt to address government deficit.

While personal consumption (B) increased and household labour (E) contributed strongly, the change in the net ISEW per capita is limited. There are a number of key items that can be identified in having a negative effect in Spain; income distribution (C), the cost of energy depletion (S) and the costs of climate change (T) are major factors. With energy being the common denominator in the reductions in costs between items O, S and T, this reduction can be attributed both to recessionary and positive policy effects. O'Mahony and Dufour (2015) showed that Spain is an unusual case internationally in that the energy intensity of the overall economy actually increased from 1990 to 1995 and only improved thereafter. In understanding this regressive development on the consumption side, Mendiluce and Schipper (2011) noted that in the transport sector there was an increase in activity and a shift in mode from bus and rail to car and air travel. Within the economic sectors, Marrero and Ramos-Real (2013) found an increase in intensity from 1990 to 2005 attributable to disimprovement in technical efficiency and only limited improvement in industry structure away from energy intensive activities. On the production side, O'Mahony and Dufour (2015) showed that from 1995 to 2011 fossil fuel substitution,

[18] The shadow price of Spanish domestic labour is valued at €6.30 per hour in 2010 prices, which is lower than Bleys (2009) at €6.72 in 2005 prices. See Item E in the supplementary materials for discussion.

the penetration of renewable energy and some increase in the output of nuclear energy, all acted to reduce carbon emissions as examples of some success in energy and mitigation policy. From 2007 to 2010 the effect of the economic recession '*la crisis*' is also evident in acting to reduce energy demand and emissions (O'Mahony and Dufour, 2015).

Data limitations have led to a number of omissions in the Spanish ISEW; volunteer work in item E, noise pollution (item P), personal pollution control (item L), soil erosion in item R and the current welfare impact cost of climate change in item T. For volunteer work, using the same hourly wage and method as for household labour, the value of volunteer work is €21.67 billion and €25.44 billion in 2003 and 2010 respectively, the years of known hourly volunteering data. For item P, the only data is available for 2009, giving a cost of €0.887 billion. Data for item L is unavailable but is typically a minor cost in ISEW studies (Bleys, 2006; Nourry, 2008). The cost of soil erosion and compaction in Spain is unknown and there are also limitations in estimation of the cost of water pollution and loss of wetlands. The costs of the current impacts of climate change in Spain were estimated by Fundación DARA Internacional (2012) as 0.5% of GDP equivalent to €5.41 billion in 2010. Aggregating the known changes above in 2010 (in Items E, P, L and T) gives a net change in ISEW per capita of + 4.12%. This change is unlikely sufficient to change the conclusions on the trend in ISEW per capita over the full period, particularly when other omissions are acknowledged. The most significant omissions are of net international investment position (Item W), net capital growth (Item V) and the cost of ozone depletion (Item U). Item V and W are not compatible with the Fisherian concept of income (Lawn, 2013) and largely cancel each other out in the Spanish ISEW. Ozone depletion (Item U) is a significant cost but it may have been over-estimated in ISEW/GPI studies. It is larger than the costs of climate change estimated in this study due to the accumulating damages. As there are limitations in knowledge of the social cost of ODS in the literature it has not been possible to update Item U. Including item U in the ISEW would reduce average welfare, but its magnitude is unlikely to affect the conclusions as the sensitivity analysis has shown. Items U, V and W have been estimated in this study but have been not included in the final index. The interested reader will find the full discussion of the method for all items in the supplementary materials and the results in the Appendix A.

4. Discussion

Within the results of an ISEW, the narrative that all growth is good and should be pursued at all costs starts to unravel. For Spain in particular, and the improvement of welfare in general, strategic policy is required that robustly considers current welfare, but also the sustainability of the path with respect to future welfare, and not just a simplistic priority on short-term economic growth. O'Mahony and Dufour (2015) outlined that it is necessary to look not only at GDP, but to consider different types of development paths and how sustainability can be implemented. This has implications not only for social and environmental policy but for core economic and development policy. Achieving balanced and win-win outcomes across different development objectives requires policy integration. It could be assisted by establishing macro-objectives of welfare or 'wellbeing' and sustainability as the framework for development. From the results of the Spanish ISEW, the fossil-fuelled high-growth approach has not lead to much benefit for average welfare. In the last decade, there have been some recent minor improvements arising due to policy changes, and also to declines in environmental impacts due to recessionary reductions in demand. The recession offers an opportunity to break with current trends, to develop a holistic future vision and to implement supporting measures. An ISEW is a tool that could assist this process, as an indicator of welfare that highlights and quantifies key factors leading to change in the aggregate.

While the ISEW can potentially conflate issues, it does provide insights which the traditional GDP cannot. Aggregating economic valuations obscures the effect of specific items only if the audience chooses to ignore the contribution of these underlying items. While a dashboard of indicators could be used (Bleys, 2008), in some circumstances an aggregated indicator may prove more useful,[19] the ISEW can also function as a bridging tool between single and dashboard indicators. GDP may be a useful income measure, but in the case of understanding welfare it is necessary to employ more specific thematic social, environmental and economic indicators, and more general and comprehensive indicators such as the ISEW. These can be used to interrogate welfare, progress and the development pathways which are intended to achieve them. It is the purpose of the measurement and the intended audience that should be considered in determining what is the appropriate indicator in each context, incorporating an understanding of its uses and limitations.

While standardisation of ISEW valuations as recommended by Lawn (2005) is an important advance, they must evolve in tandem with the goals of society and the understanding of the challenges that they seek to address (Bagstad et al., 2014). The perceived simplicity of GDP appears useful in some circumstances, yet it is this simplicity which becomes its weakness in the face of more complex and value-laden problems such as welfare measurement. The ISEW and advances in its valuation then become a potential strength, as it seeks to respond to the inevitable subjectivity of welfare in general and sustainability in particular (Bleys, 2008). Neumayer (2004) questions the conflation of current welfare and future sustainability, but as illustrated by ongoing debates such those on SCC's, this conundrum is one which both analysis and policy continue to struggle with. Nonetheless, the ISEW cannot be used in policy debates without supporting thematic indicators (Lawn, 2003), and in some cases flashing red lights. An improving ISEW is of moot value if in parallel the planet is on course for potential catastrophic impacts such as those from climate change and biodiversity loss.

It is useful to examine the implications of the updated valuation approaches with respect to the Fisherian concept of income, the theoretical basis for ISEW/GPI. While Fisher (1906) sought to measure 'psychic income' experienced in a particular year, the extended version of Fisher's income (Lawn, 2008) includes the 'uncancelled costs' of lost natural capital services that are consumed in the economic process as per Daly (1979). Long-term environmental damage through the impacts of climate change is one of these uncancelled costs. As current modelled SCC's include only some of the impacts on natural capital, and also include some impacts on human capital in the form of health, SCC's currently offer a limited approximation of the lost natural capital services that the extended Fisherian income concept requires. Rectifying this would involve advances in integrated assessment modelling that address known limitations in estimating damages to natural capital as discussed in Section 2.2. In the absence of these modelling advances, using current estimates of the SCC is seen as an appropriate compromise in the face of unknowns, but higher rates for SCC's should be chosen. Responding to the theoretical requirements of extended Fisherian income is more straightforward in the case of energy depletion in the new 'transition cost' approach. It functions as a direct valuation of natural capital depletion similar to the replacement cost of non-renewable energy of Cobb and Cobb (1994) based on advances in knowledge of future energy transition costs. The modelling studies of transition do not involve the same layers of complexity in valuing future damages to natural capital from the impacts of climate change.

The effect of using the new approaches to calculating and valuing the costs of energy depletion and of climate change have been compared against those resulting from the established approaches in ISEW/

[19] As suggested by Bleys (2008), the UN and World Bank favour satellite accounts yet this can imply that the environmental and social indicators are of less importance and lead to difficulties in user-interpretation. A single index may indeed be more suitable for communication in some contexts, but any direct use in policymaking requires disaggregation of the items.

GPI studies. The new 'transition cost' approach to energy depletion is significantly lower than the original approach of Cobb and Cobb (1994), who employed a replacement cost and an escalating cost factor,[20] and it is also lower than the updated approach developed by Bleys (2008), which used the same replacement cost but without escalation. The effect of these alternative valuations on the overall ISEW per capita, is that the index shows a minor improvement when using the transition cost and replacement cost approaches, but almost no improvement when costs are escalated as per Cobb and Cobb. The new transition cost approach leads to a refinement of the costs of energy depletion but it does not change the broad conclusions. The gap in welfare increases as measured by the ISEW per capita has widened and is far below the increase in GDP per capita. This holds even when excluding the significant drag on welfare of escalating the costs of energy depletion by 3% per annum.

For the damage costs of climate change, the new approach in this study adopts a higher SCC from Ackerman and Stanton (2012),[21] but with no accumulation of costs. The results are compared against: i) an alternative lower SCC from Fankhauser (1994) with the same approach to calculation,[22] and, ii) the approach taken by Jackson et al. (1997) which used this lower Fankhauser SCC but accumulated the costs each year. Using the lower Fankhauser SCC has a minor effect on the overall ISEW per capita index and it is not sufficient to change the broad conclusions. Accumulating the cost of damages as per Jackson et al. (1997) is sufficient to turn the ISEW per capita from a minor improvement over the study period into a decline. It is evident that accumulating the cost of climate change damages is a significant drag on welfare as measured by the ISEW per capita. Nevertheless, there remains a resounding difference between the ISEW and GDP per capita when this accumulation is excluded. The removal of the cost of ozone depletion following the recommendation of Bagstad et al. (2014) affects the index, but it is also insufficient to change the conclusions. Neumayer (2000) proposed that the 'threshold hypothesis' put forward in ISEW/GPI studies could be an artificial construct, an artefact of highly contestable methodological assumptions on cost escalation of energy depletion and accumulating the costs of climate change. Neumayer suggested the threshold effect may fail to materialise if these two assumptions were abandoned. It is clear in the Spanish case that this does not hold and the emergence of the threshold effect is independent of these assumptions. There is indeed a significant difference between the ISEW and GDP per capita even when these two methodological assumptions are discarded.

5. Concluding Remarks

The ISEW has been applied to many countries and regions since its inception, this study extends it to Spain from 1970 to 2012. While the overall structure of the index has not changed much since its introduction, two cost valuations; non-renewable energy depletion and the costs of climate change have proven controversial. Changes to valuation approaches are necessary as they must be updated to reflect advancements in knowledge and indeed policy priorities (Bagstad et al., 2014). The Spanish ISEW reviewed and endeavoured to update and simplify these valuations, accounting for notable criticisms of prior approaches. Following the recommendation of Bagstad et al. this study also reviews the approach and place of the calculation of the costs of ozone depletion and of water pollution. The Spanish ISEW may enhance understanding of national development progress and act as a starting point for further improvement of national accounting and measurement of welfare. As measured by the ISEW, improvement in average welfare in Spain has been limited and high GDP growth has been accompanied by hidden costs. While GDP per capita increased markedly there is a widening gap with ISEW per capita. The most significant contributors to the index include on the positive side; personal consumption expenditure and household labour, and on the negative; income distribution inequality, energy depletion and the costs of climate change. It is noteworthy that the modifications to update the valuations, while they reduce the widening gap between the ISEW and GDP per capita, a widening gap nevertheless emerges. However, when the comparator of accumulating the costs of climate change is used following the approach of previous ISEW studies, the index changes from a minor improvement to a decline. Accumulating the costs of climate change is not an appropriate application of the Social Cost of Carbon, which theoretically includes all future damage costs discounted to the present. Including the escalating cost factor with a replacement cost for energy depletion changes the trend in the ISEW from a minor improvement to essentially no improvement. Neumayer (2000) suggested that contrary to the 'threshold hypothesis' of Max-Neef (1995) that if the escalating cost factor for non-renewable resource depletion (energy) and the cumulative of long-term environmental degradation (costs of climate change) were removed, that the widening gap between ISEW/GPI and GNP/GDP may disappear. While the modified valuations in this study do not lead to an ISEW with an overall decline in welfare, they do support a widening gap, consistent with Max-Neef's threshold hypothesis.

Energy is a significant factor in the index as it affects not only energy depletion and climate change, but also air pollution. In policy-making, such thematic issues should be central to the macro issues of development pathways, sustainability and welfare maximisation to deliver co-benefits and synergies. Consumption does not equal welfare or wellbeing (Fleurbaey et al., 2014; Lawn, 2003; Lawn, 2005) and the ISEW/GPI which reduces economic welfare as measured by consumption,by the costs associated with social and environmental ills, does not measure sustainability per se (Stiglitz et al., 2009). Lawn (2003) and Bleys (2006) have defended the handling of sustainability, proposing necessary supplemental accounts. If its use is to be furthered, important areas for research may include overconsumption in current welfare, and limits, thresholds and non-substitutable capital to address sustainability. An additional dashboard could be added that highlights ecologically unsustainable developments (Lawn, 2003). The ISEW is a useful index; as an integrated indicator of progress, as a communication tool, and as it contrasts GDP by correcting it for factors not usually accounted for. It will only be of direct use in policymaking if it is fully disaggregated, and as with all indicators it does have limitations. The monetisation of damages can satisfy economic externalities but not necessarily the ethical and risk issues where options are foreclosed and not all capital is perfectly substitutable. Users must also recognise that current welfare does not necessarily equal long-term sustainability. In promoting discourse on sustainability, welfare and progress, the ISEW could be a valuable replacement of the monetary flows of GDP. Deciding to use the ISEW/GPI requires an awareness of its limitations, and consideration of; what is it that actually requires measurement, who will be the audience, and are other supporting indicators required? The ISEW is a measure of welfare that uses sustainability accounting methods when estimating costs (Lawn, 2013), but it is not an indicator of whether welfare is actually sustainable (Lawn, 2003).

Acknowledgements

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[20] Using a replacement cost of $75 per barrel of oil equivalent (BOE) in 1988$, and an escalating the cost factor of 3% per annum to account for the increasing costs of supplying each marginal unit of energy.

[21] The SCC is valued at $232 in 2010$ per tonne of CO_2 from Ackerman and Stanton (2012). This is varied per year throughout the study period on the basis of the damage curve included in Ackerman and Stanton and there is no accumulation of costs.

[22] Using an SCC valued at $20 per tonne of CO_2 in 1990 from Fankhauser (1994), varied per year using the damage curve originally included in Fankhauser, and with no accumulation of costs.

assistance with German translation.

Appendix A. Appendix

Table A1
Items A to N in the index of sustainable economic welfare for Spain from 1970 to 2012 in million 2010€.

A	B	C	D	E	F	G	H	I	J	K	M	N
Year	Personal consumption	Gini coeffic.	Weighted consumption	Household labour	Services of consumer durables	Roads	Public health and education	Cost of consumer durables	Private health and education	Commuting	Road accidents	Water poll.
	+	−	+	+	+	+	+	−	−	−	−	−
1970	186,256	0.35	137,773	301,689	3,486	771	6,925	15,493	12,316	5,431	11,013	2,010
1971	195,522	0.36	143,946	304,051	3,427	833	8,043	15,230	12,384	5,610	11,356	2,022
1972	210,803	0.36	154,468	305,007	4,631	850	9,626	20,583	12,447	7,086	11,711	2,034
1973	226,795	0.37	165,411	306,121	5,475	901	11,413	24,331	12,282	7,807	12,076	2,046
1974	239,798	0.36	176,795	307,095	5,869	949	12,435	26,085	11,912	8,624	12,453	2,058
1975	245,386	0.34	182,903	308,548	5,993	965	14,031	26,634	11,585	8,536	12,467	2,068
1976	259,638	0.33	195,677	310,122	5,922	1,057	14,928	26,320	11,138	9,507	13,069	2,079
1977	264,542	0.31	201,613	312,061	5,420	1,040	16,359	24,089	10,310	10,114	13,498	2,090
1978	268,889	0.30	207,254	313,934	5,080	1,259	17,327	22,576	9,614	10,026	14,659	2,101
1979	273,719	0.28	213,402	317,016	4,871	1,251	17,447	21,649	9,177	10,393	14,680	2,112
1980	280,057	0.27	220,882	315,850	4,631	1,405	17,976	20,580	8,378	10,560	13,994	2,122
1981	279,773	0.26	221,217	317,336	4,169	1,438	17,828	18,529	8,255	10,607	13,860	2,133
1982	282,335	0.26	223,809	317,208	4,161	1,659	18,514	18,495	8,439	10,450	12,979	2,144
1983	284,980	0.26	226,480	316,953	4,262	1,738	20,446	18,942	8,452	11,054	13,933	2,155
1984	285,562	0.26	227,522	316,413	3,937	1,906	19,304	17,498	8,185	11,026	14,559	2,166
1985	293,251	0.25	234,245	315,737	4,244	2,154	19,095	18,863	8,316	11,085	15,416	2,178
1986	303,970	0.26	241,246	314,908	5,028	3,359	19,613	22,345	8,499	11,621	16,953	2,190
1987	324,061	0.26	257,621	313,826	6,116	3,493	21,097	27,184	8,739	13,063	18,856	2,203
1988	339,069	0.24	272,519	312,647	6,797	3,523	24,707	30,209	9,467	14,120	20,176	2,215
1989	359,508	0.26	285,528	311,385	7,131	3,667	26,375	31,694	10,117	15,068	21,610	2,228
1990	374,233	0.27	294,074	310,021	6,663	4,428	29,357	29,611	10,752	13,985	21,190	2,241
1991	387,586	0.29	301,373	308,483	6,367	4,656	30,932	28,296	11,687	14,405	20,651	2,253
1992	397,144	0.30	305,602	307,096	6,459	4,209	32,991	28,705	12,559	15,296	17,662	2,265
1993	393,641	0.31	299,796	305,690	5,571	4,152	33,650	24,760	13,267	15,316	16,973	2,276
1994	397,409	0.33	299,589	304,166	6,059	4,248	33,068	26,928	13,733	16,266	15,331	2,288
1995	430,282	0.34	321,106	302,487	4,700	3,989	34,150	20,889	10,424	13,458	15,896	2,304
1996	445,502	0.34	332,464	300,734	5,058	3,468	35,000	22,482	10,984	14,359	15,199	2,316
1997	450,691	0.35	333,845	288,598	5,605	2,903	35,913	24,912	11,019	14,978	15,373	2,628
1998	470,298	0.34	350,969	276,548	6,370	3,072	37,314	28,313	11,506	15,811	16,108	2,939
1999	498,004	0.33	374,439	264,765	7,234	3,140	39,096	32,149	12,174	17,226	15,247	3,149
2000	523,953	0.32	396,934	253,416	6,862	3,257	40,176	30,499	12,607	17,851	14,494	1,432
2001	539,884	0.33	405,928	263,327	6,889	3,322	41,668	30,618	13,029	17,967	13,895	1,438
2002	550,541	0.31	420,260	274,101	6,262	3,406	43,997	27,832	13,409	17,496	13,563	1,511
2003	566,513	0.31	432,452	286,500	6,431	3,494	47,007	28,581	13,957	17,810	13,687	1,394
2004	590,886	0.31	451,058	292,147	7,055	3,506	49,264	31,354	14,429	18,989	11,791	2,856
2005	613,501	0.32	464,070	298,041	7,230	3,725	50,962	32,132	14,943	20,376	11,361	2,702
2006	637,825	0.32	483,567	303,694	7,352	3,918	53,819	32,674	15,211	21,423	10,871	2,259
2007	660,756	0.32	500,952	309,816	7,373	4,108	56,824	32,768	15,546	22,207	10,055	2,248
2008	652,653	0.32	494,809	316,698	6,421	4,102	60,180	28,539	15,565	21,851	8,423	2,237
2009	621,898	0.33	467,592	321,452	5,333	4,286	63,357	23,702	15,442	19,736	7,334	2,226
2010	623,812	0.34	464,146	323,948	5,099	4,227	61,373	22,661	15,571	20,405	6,587	2,215
2011	615,691	0.35	457,763	325,984	4,491	2,684	57,615	19,962	15,179	20,220	5,857	2,204
2012	599,652	0.35	444,187	327,844	4,035	2,561	52,382	17,932	15,276	19,701	5,460	2,193

Table A2
Items O to AB in the Index of Sustainable Economic Welfare for Spain from 1970 to 2012 in million 2010€.

A	O	Q	R	S	T	*U*	*V*	*W*	X	Y	Z	AA	AB
Year	Air pollution	Wetlands	Gain/ loss agricultural land	Energy depletion	Climate change	*Ozone depletion*[b]	*Net capital growth*[b]	*Investment position*[b]	Total ISEW	Population	GDP	ISEW/ capita[a]	GDP/ capita[a]
	−	+	+/−	−	−	−	+	+					
1970	25,333	0	− 961	27,194	9,410	*2,386*	*47,951*	*− 17,630*	341,483	33,587,610	334,535	10,167	9,960
1971	27,470	0	− 1,077	28,178	10,565	*4,772*	*47,951*	*− 17,630*	346,407	34,041,452	348,827	10,176	10,247
1972	29,773	0	− 1,167	28,990	12,148	*7,158*	*47,951*	*− 17,630*	348,644	34,341,903	378,053	10,152	11,008
1973	32,222	0	− 1,263	29,853	13,278	*9,544*	*47,951*	*− 17,630*	354,161	34,663,507	409,178	10,217	11,804
1974	34,101	0	− 1,337	31,103	15,097	*11,930*	*47,951*	*− 17,630*	360,374	34,970,634	433,019	10,305	12,382
1975	34,243	0	− 1,343	31,950	16,158	*14,316*	*62,442*	*− 12,566*	367,455	35,338,041	434,831	10,398	12,305
1976	35,032	0	− 1,374	34,558	18,010	*16,702*	*62,442*	*− 12,566*	376,619	35,723,408	444,846	10,543	12,453
1977	35,695	0	− 1,400	33,883	18,117	*19,088*	*62,442*	*− 12,566*	387,296	36,155,465	453,272	10,712	12,537
1978	36,474	0	− 1,430	35,067	18,940	*21,474*	*62,442*	*− 12,566*	393,967	36,584,635	463,155	10,769	12,660
1979	36,887	0	− 1,446	36,204	19,637	*23,860*	*62,442*	*− 12,566*	401,801	37,160,377	468,405	10,813	12,605
1980	36,679	0	− 1,438	38,203	21,141	*26,246*	*34,953*	*− 8,812*	407,648	37,241,868	469,656	10,946	12,611
1981	35,980	0	− 1,411	37,944	20,795	*28,632*	*34,953*	*− 8,812*	412,474	37,636,201	460,002	10,959	12,222
1982	36,390	639	− 1,427	37,939	21,484	*31,018*	*34,953*	*− 8,812*	416,244	37,844,910	462,375	10,999	12,218
1983	37,060	647	− 1,453	37,532	21,393	*33,404*	*34,953*	*− 8,812*	418,551	38,040,699	469,330	11,003	12,338
1984	37,722	647	− 1,426	38,509	21,195	*35,790*	*34,953*	*− 8,812*	417,444	38,204,159	475,948	10,927	12,458
1985	38,307	647	− 1,458	39,261	21,872	*38,176*	*− 115*	*− 8,368*	419,364	38,352,991	486,003	10,934	12,672
1986	40,358	647	− 1,502	41,165	21,121	*40,562*	*− 115*	*− 8,368*	419,046	38,484,642	511,418	10,889	13,289
1987	42,878	647	− 1,618	42,581	21,595	*42,880*	*− 115*	*− 8,368*	424,084	38,586,591	543,367	10,990	14,082
1988	45,441	647	− 1,730	43,845	22,973	*45,129*	*− 115*	*− 8,368*	430,664	38,675,049	577,016	11,135	14,920
1989	47,727	918	− 1,723	48,572	26,693	*47,310*	*− 115*	*− 8,368*	429,572	38,756,648	605,462	11,084	15,622
1990	49,788	918	− 1,569	47,081	24,511	*48,979*	*33,315*	*− 12,776*	444,733	38,826,297	631,938	11,454	16,276
1991	50,896	918	− 442	49,248	26,141	*50,769*	*33,315*	*− 12,776*	448,709	38,874,573	654,144	11,542	16,827
1992	51,059	918	− 366	50,837	27,958	*52,944*	*33,315*	*− 12,776*	450,565	39,003,524	665,115	11,552	17,053
1993	48,741	1,042	− 349	48,491	27,500	*54,866*	*33,315*	*− 12,776*	452,228	39,131,966	658,057	11,556	16,816
1994	49,064	1,233	− 147	51,291	29,436	*56,191*	*33,315*	*− 12,776*	443,878	39,246,833	668,344	11,310	17,029
1995	46,941	1,233	− 149	55,601	31,914	*56,576*	*− 5,773*	*− 26,440*	470,089	39,343,100	688,469	11,948	17,499
1996	44,968	1,235	− 417	54,222	30,884	*56,959*	*− 5,773*	*− 26,440*	482,129	39,430,933	706,285	12,227	17,912
1997	45,919	1,235	− 467	58,275	33,090	*57,413*	*− 5,773*	*− 26,440*	461,439	39,525,438	735,296	11,674	18,603
1998	44,654	1,235	3,930	61,021	34,607	*57,807*	*− 5,773*	*− 26,440*	464,481	39,639,388	772,224	11,718	19,481
1999	44,723	1,235	4,279	64,511	38,638	*58,220*	*− 5,773*	*− 26,440*	466,370	39,802,827	809,650	11,717	20,342
2000	43,634	1,235	4,422	67,486	41,181	*58,604*	*66,697*	*− 60,754*	477,119	40,049,708	851,183	11,913	21,253
2001	42,407	1,235	− 6,056	68,642	41,721	*59,088*	*66,697*	*− 60,754*	486,596	40,476,723	889,416	12,022	21,974
2002	43,028	1,318	− 6,243	71,408	45,364	*59,547*	*66,697*	*− 60,754*	509,492	41,035,278	924,336	12,416	22,525
2003	41,097	1,304	− 6,457	72,927	47,282	*59,894*	*66,697*	*− 60,754*	533,995	41,827,838	961,937	12,766	22,998
2004	41,318	1,304	− 1,086	76,970	50,569	*60,205*	*66,697*	*− 60,754*	554,972	42,547,451	1,000,911	13,044	23,525
2005	40,215	1,304	− 1,131	78,673	54,034	*60,459*	*82,749*	*− 115,832*	569,765	43,296,338	1,046,007	13,160	24,159
2006	38,574	1,304	311	78,186	53,732	*60,669*	*82,749*	*− 115,832*	601,034	44,009,971	1,094,536	13,657	24,870
2007	37,668	1,588	322	79,260	55,706	*60,765*	*82,749*	*− 115,832*	625,527	44,784,666	1,141,805	13,967	25,495
2008	29,564	1,605	− 9,461	76,194	51,881	*60,857*	*82,749*	*− 115,832*	640,103	45,668,939	1,133,024	14,016	24,810
2009	26,881	1,707	− 9,048	68,028	46,321	*60,958*	*82,749*	*− 115,832*	645,010	46,239,273	1,098,454	13,949	23,756
2010	25,623	1,605	− 8,632	66,634	44,964	*61,053*	*− 22,889*	*9,444*	647,106	46,486,619	1,080,913	13,920	23,252
2011	25,575	1,707	− 4,451	66,268	45,862	*61,144*	*− 22,889*	*9,444*	644,667	46,667,174	1,041,847	13,814	25,575
2012	24,513	1,707	− 4,215	65,485	45,968	*61,230*	*− 22,889*	*9,444*	631,972	46,818,219	998,065	13,498	24,513

[a]ISEW/capita and GDP/Capita in €2010, all other monetary items in million €2010.
[b]Items U,V and W were estimated as part of the study but omitted from the final index as per Section 2 Methodology.

Appendix B. Supplementary Materials

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.ecolecon.2017.07.024.

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